



**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**

# Long Term Hydrogen Vehicle Fleet Operational Assessment

Steven Eick

Tank and Automotive Research, Development, and Engineering Center, National Automotive Center

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE <b>21 MAR 2011</b>		2. REPORT TYPE <b>N/A</b>		3. DATES COVERED <b>-</b>	
4. TITLE AND SUBTITLE <b>Long Term Hydrogen Vehicle Fleet Operational Assessment</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) <b>Steven Eick</b>				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>US Army RDECOM-TARDEC 6501 E 11 Mile Rd Warren, MI 48397-5000, USA</b>				8. PERFORMING ORGANIZATION REPORT NUMBER <b>21643</b>	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) <b>US Army RDECOM-TARDEC 6501 E 11 Mile Rd Warren, MI 48397-5000, USA</b>				10. SPONSOR/MONITOR'S ACRONYM(S) <b>TACOM/TARDEC/RDECOM</b>	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S) <b>21643</b>	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release, distribution unlimited</b>					
13. SUPPLEMENTARY NOTES <b>The original document contains color images.</b>					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>SAR</b>	18. NUMBER OF PAGES <b>16</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

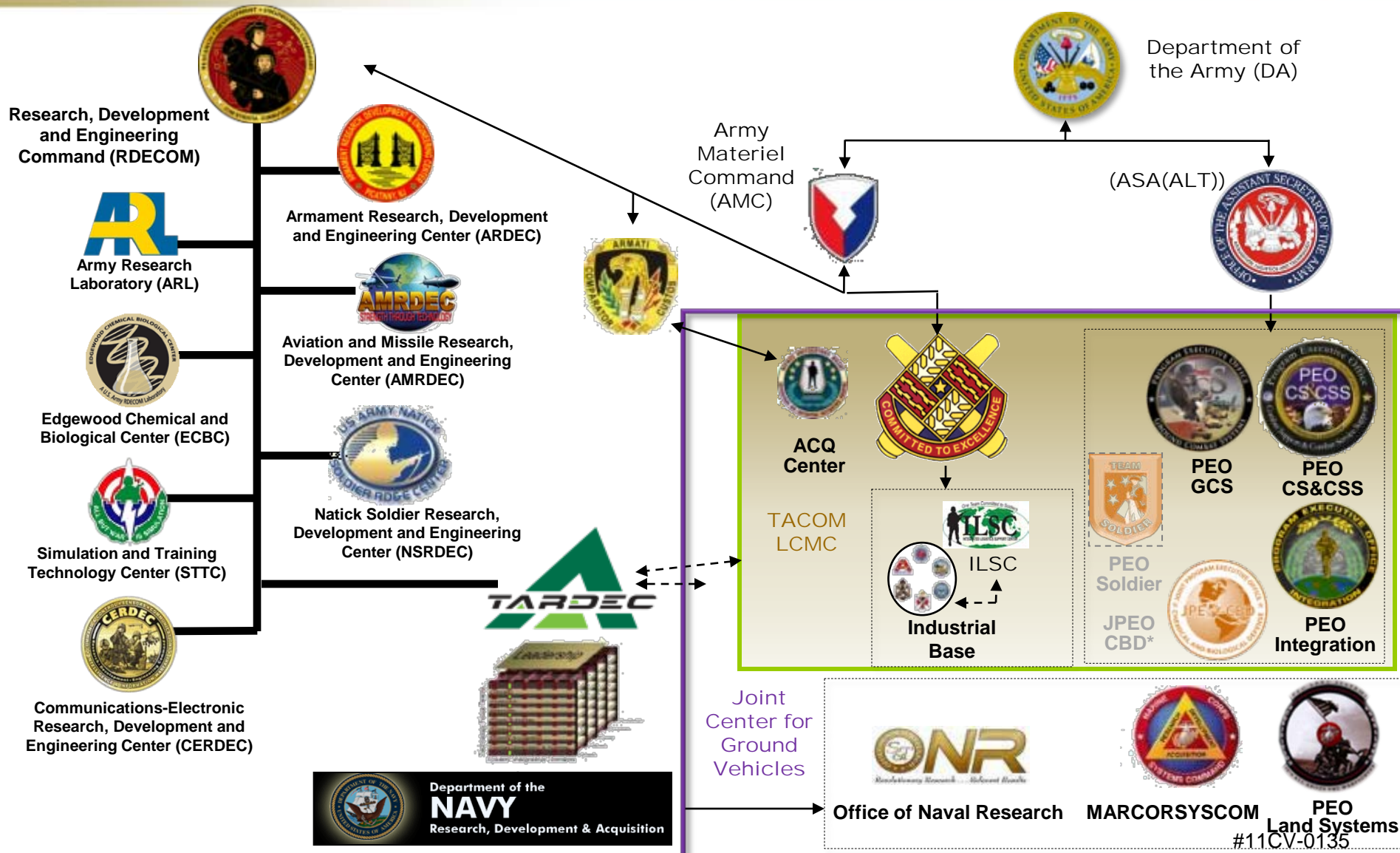
Unclassified FOUO

- Provides full life-cycle engineering support and is provider-of-first-choice for all DOD ground combat and combat support vehicle systems.
- Develops and integrates the right technology solutions to improve Current Force effectiveness and provide superior capabilities for the Future Force.



Responsible for Research, Development and Engineering Support to **2,800** Army systems and many of the Army's and DOD's Top Joint Warfighter Development Programs

**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**





# U.S. Army National Automotive Center (NAC)



**Chartered by Secretary of the Army 21 June 1993**



## **Mission:**

**“The Center will serve as the Army focal point for the development of dual-use automotive technologies and their application to military ground vehicles. It will focus on facilitating joint efforts between industry,**

***“Leveraging Opportunities to Fill Technology Gaps.”***

**“Accelerating the infusion of commercially viable technology into military land warfare systems”**

**and professional development.”**

**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**

- **Purchased ten Hydrogen Hybrid Internal Combustion Engine (H2ICE) vehicles in 2008**
  - Converted gasoline hybrid to be operated on hydrogen
  - Operated for first year at multiple locations
  - Fitted with data acquisition equipment to record vehicle performance
- **Fleet consolidated to one location in July 2009 in Hawaii**



#11CV-0135

**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**

- **Project Goals:**
  - To demonstrate applicability of hydrogen vehicles for non-tactical fleets at military installations
  - To investigate long-term effects of the conversion process on the performance of the vehicle
- **Project tracked fleet of vehicles from July 2009 to January 2011 recording vehicle performance, driver feedback and maintenance actions performed on the vehicles.**

- **Island of Oahu, Hawaii selected as fleet deployment site**
  - DoD presence on Oahu - Army, Navy, Air Force, Pacific Command, Coast Guard and National Guard
  - Organizational Interest from installations
  - Availability of Hydrogen
- **Drivers were selected based on expected vehicle utilization and interest in the technology**
  - Goal of 200 miles per month per vehicle
  - Require vehicle during their average workday
  - Proximity to hydrogen refueling station

- **Standard MY 2008 Hybrid Gasoline Electric Sport Utility Vehicle converted to burn gaseous hydrogen instead of gasoline**



#11CV-0135

**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**

Unclassified: Dist. A. Approved for Public Release

- **Conversion Process**

- Replaced 15 gallon gasoline fuel system with carbon-fiber hydrogen tanks and hydrogen fuel lines.
- Storage of 3.8 kg hydrogen at 350 bar.
- Standard gasoline engine with replacement fuel injectors, spark plugs and air filter.
- Added a turbocharger to recover engine power lost from converting to gaseous fuel.
- Installation of hydrogen sensors

- **Vehicles had published range of 100 miles; actual distance driven varied depending on driver and local conditions.**

- **Data collected through the CANbus on the engine, hybrid battery and vehicle operation.**
- **Temperature and Pressure Sensors recorded the state of the hydrogen storage tanks.**

#11CV-0135

**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**

- **Electrical Problems with Hydrogen Fuel System**
  - Hydrogen Sensors
  - Fuel Gauge Module
  - Addressed through replacing the faulty equipment
- **Vehicle Performance on Steep Grades**
  - Hydrogen consumption on steep hills limited vehicle range
  - Addressed through Driver Training on vehicle limitations
- **Driver Concern with Continuously Variable Transaxle and Turbo Lag**
  - Driver reports of high engine speeds and improper shifting
  - Driver reports of lacking power from Turbolag
  - Addressed through additional training

<b>Vehicle Number</b>	<b>Miles Travelled (mi)</b>	<b>Hydrogen Usage (kg)</b>
<b>1</b>	<b>1272</b>	<b>47.3</b>
<b>2</b>	<b>1331</b>	<b>53.3</b>
<b>3</b>	<b>905</b>	<b>39.0</b>
<b>4</b>	<b>2624</b>	<b>116.5</b>
<b>5</b>	<b>1420</b>	<b>55.2</b>
<b>6</b>	<b>3651</b>	<b>109.0</b>
<b>7</b>	<b>7765</b>	<b>244.8</b>
<b>8</b>	<b>5238</b>	<b>205.9</b>
<b>9</b>	<b>1955</b>	<b>89.8</b>
<b>10</b>	<b>4165</b>	<b>152.9</b>

<b>Vehicle Number</b>	<b>Average Fuel Economy (mi/kg)</b>	<b>Average Fuel Economy (mi/gge)</b>
<b>1</b>	<b>26.9</b>	<b>26.8</b>
<b>2</b>	<b>25.0</b>	<b>24.9</b>
<b>3</b>	<b>23.2</b>	<b>23.1</b>
<b>4</b>	<b>22.5</b>	<b>22.4</b>
<b>5</b>	<b>25.7</b>	<b>25.6</b>
<b>6</b>	<b>33.5</b>	<b>33.4</b>
<b>7</b>	<b>31.7</b>	<b>31.6</b>
<b>8</b>	<b>25.4</b>	<b>25.3</b>
<b>9</b>	<b>21.8</b>	<b>21.7</b>
<b>10</b>	<b>27.2</b>	<b>27.1</b>

#11CV-0135

**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**

Unclassified: Dist. A. Approved for Public Release

- Average fuel economies varied greatly between vehicle
- Fleet Fuel Economy was 26.2 mi/kg or 26.1 mi/gge
- The fuel economy of the fleet of H2ICEs was comparable to the standard hybrid-electric gasoline SUVs

- **Effects of Water on Exhaust and Engine Lubrication**
  - **Muffler showed internal oxidation**
    - **Required earlier replacement than Gasoline vehicle**
    - **Replaced with Stainless Steel muffler**
    - **Traced back to increased water in the exhaust system**
  - **Water contamination in engine oil**
    - **Water condensed during initial warm-up, entering crankcase**
    - **Related to local temperatures**
    - **Premature oil breakdown**
- **Starting Battery**
  - **Minor parasitic draw on the battery**
  - **Cause traced back to vehicle electronics combined with hydrogen fuel system parasitic load**
  - **Consistent operation of the vehicle maintains battery life**

- **H2ICEs were an equivalent replacement to gasoline non-tactical vehicle**
- **H2ICE range and fueling were issues to the drivers**
- **Maintenance was generally equivalent, except additional effort to maintain oil quality**
- **Some performance issues noted by drivers were due to the other systems, not the hydrogen conversion**

# Any Questions?

For more information please contact Steven Eick - [Steven.Eick1@us.army.mil](mailto:Steven.Eick1@us.army.mil)